NZ Applied Technologies

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February 1, 1995

Program Officer
Office of Naval Research
800 North Quincy St.
Arlington, VA 22217-5660

Attention: Dr. Richard Brant, ONR Code 312

Dr. Brant,

This is the second bi-monthly progress report under STTR Contract N00014-94-C-0230 entitled, "Novel Growth Method for High Quality GaN Heteroepitaxy".

During this reporting period, NZ Applied Technologies has placed the plasma MOCVD reactor back in service and been growing GaN since early January. The we have grown both undoped and Mg-doped GaN. The best results to date are for GaN grown between 650-750°C. These films show relatively broad rocking curve FWHM values of about 0.2 deg. but have strong PL both at room temperature as well as 77 and 10 K. The group at MIT under Prof. L. Kolodziejski provided the PL measurements.

Samples were sent to Prof. Ho's group at Cornell for Raman measurements and to Prof. Schaaf's group for Hall effect measurements. The results of the Raman measurements on Sample 617 [2μm thick] are shown in Fig .1. The Raman peaks are sharp and intense. Sample 617 showed strong luminescence during the measurement.

The highest Hall mobilities measured were 150 cm^2/v-sec, for carrier concentrations in the 10^{18} cm^3 range.

The balance of this report consists of the progress under Prof. Wilson Ho's subcontract at Cornell University.

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2. The Defense Technical Information Center received the enclosed report (referenced below) which is not marked in accordance with the above reference.

PROGRESS REPORT #2
N00014-94-C-0230
TITLE: NOVEL GROWTH FOR HIGH
QUALITY GaN HETEROEPITAXY

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A

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Debra Hughes

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19 SEP 1995

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During this past two months, successful growth of single crystal AlN on Si(100) was accomplished. The Si(100) substrate was first sputter cleaned, with Auger showing a surface without any contamination. The 3/4"x3/4" substrate was then introduced into the growth chamber via a load-lock transfer system. Supersonic gas beams of triethylaluminum (TEA) and ammonia (NH_3) were used as the aluminum and nitrogen sources, respectively. The base pressure of the growth chamber was 5×10^{-10} Torr, which increased to 5×10^{-6} Torr during the growth. Single crystal films were grown if these precursors were seeded in helium. The films grown with nitrogen as the seed gas were poor visually and gave no discernible x-ray diffraction peaks. Since the precursors are accelerated to higher energies when seeded in helium compared to nitrogen, these results point out the important role incident translational energy has on the growth of thin films. It is believed that the extra translational energy enhances the two- dimensional diffusion of the growth species on the surface, leading to improved conditions for single crystal growth. The thickness of the AlN films range from 0.5 μm to 1 μm. The AlN films are hexagonal; x-ray diffraction shows the FWHM of the (002) diffraction peak in the Θ-2Θ scan to be in the range 0.45 degrees to 0.28 degrees, depending on the growth conditions, as shown in Fig. 2. A thin buffer layer of AlN is grown first at 450 °C, followed by growth at a higher temperature of 600 - 700 °C. Auger spectra taken after the growth show small amount of carbon and oxygen contamination in addition to the expected Al and N peaks. Most of the FWHM is believed to be due to the large lattice mismatch between the Si(100) substrate and the AlN film.

To date, both single crystals of GaN and AlN films have been successfully grown on Si by the use of supersonic gas jets with FWHM in the Θ-2Θ scans of about 0.3 degrees. The dependence on the carrier gas was strikingly observed for both films. Further improvements of these films with growth on the SiC substrate and a SiC thin film first grown on Si are planned for the next two months, as well as electrical measurements on these films.

Raman spectra on GaN films growth on sapphire by remote plasma MOCVD at NZ Applied Technologies have been measured with the state-of-the-art micro- and macro-Raman spectrometer at Cornell University. The FWHM in the Θ-2Θ scans of these films lies in the range 0.25 - 0.30 degrees. Strong photoluminescence is observed, however, from these films.

The construction of the apparatus for the growth of thin films with slit-nozzles is progressing rapidly. It is expected that towards the end of the next two months (April), growth of SiC, GaN, and AlN will commence on 4-inch diameter Si wafers. The base pressure of the growth chamber will be in the 10^{-10} Torr range, with the pressure increased to 10^{-2} Torr range during the growth. This pressure range lies in-between our current operating pressures and those used in MOCVD. The ability to grow such large area films is especially attractive to the industry.

Sincerely,

Peter E. Norris

Dr. Peter E. Norris
Principal Investigator

APPLICATIONS LAB D.I.L.O.R. Version 3.00	
EG&G DILOR XY	

OPERATOR: JFT
DATE : 26-1-1995
SAMPLE : Gan617
GRATING : 120M
TREAT. : /
REMARK : 1200 macro 300sec -y (zx) y 295K

EXCITATION (nm) : 514.532
LASER POW. (mW) : 10
FOREMONO. (cm-1) : 0800.1
SPECTRO. (cm-1) : 0800.1
SLIT WIDTH (fm) : 150

SPECT.SLIT WIDTH (cm-1) : 5.28
DETECTOR : 1024
FILTER :
INTEGRATION TIME (s) : 0300.00
NUMBER OF ACCUMULATIONS: 1

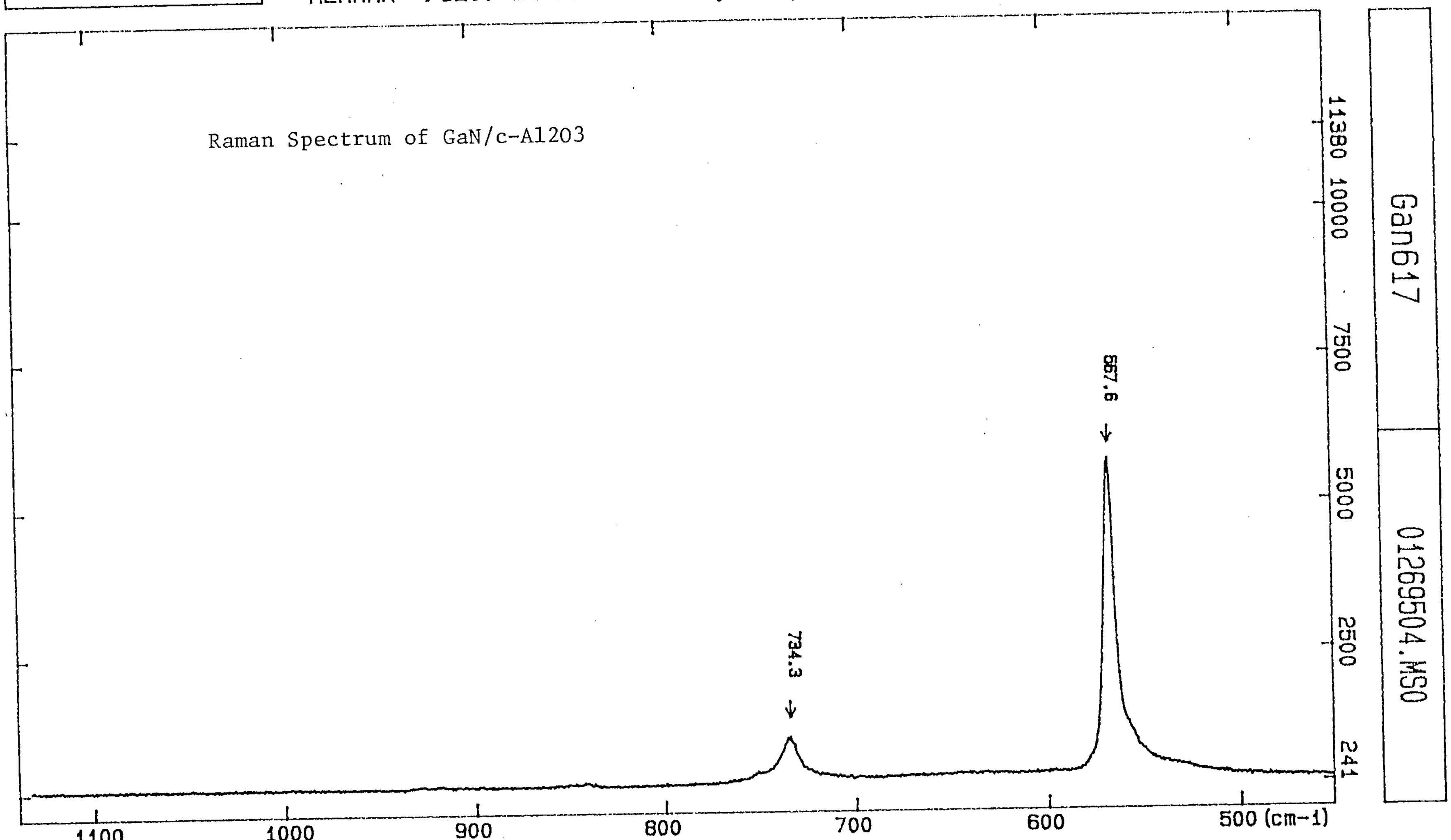
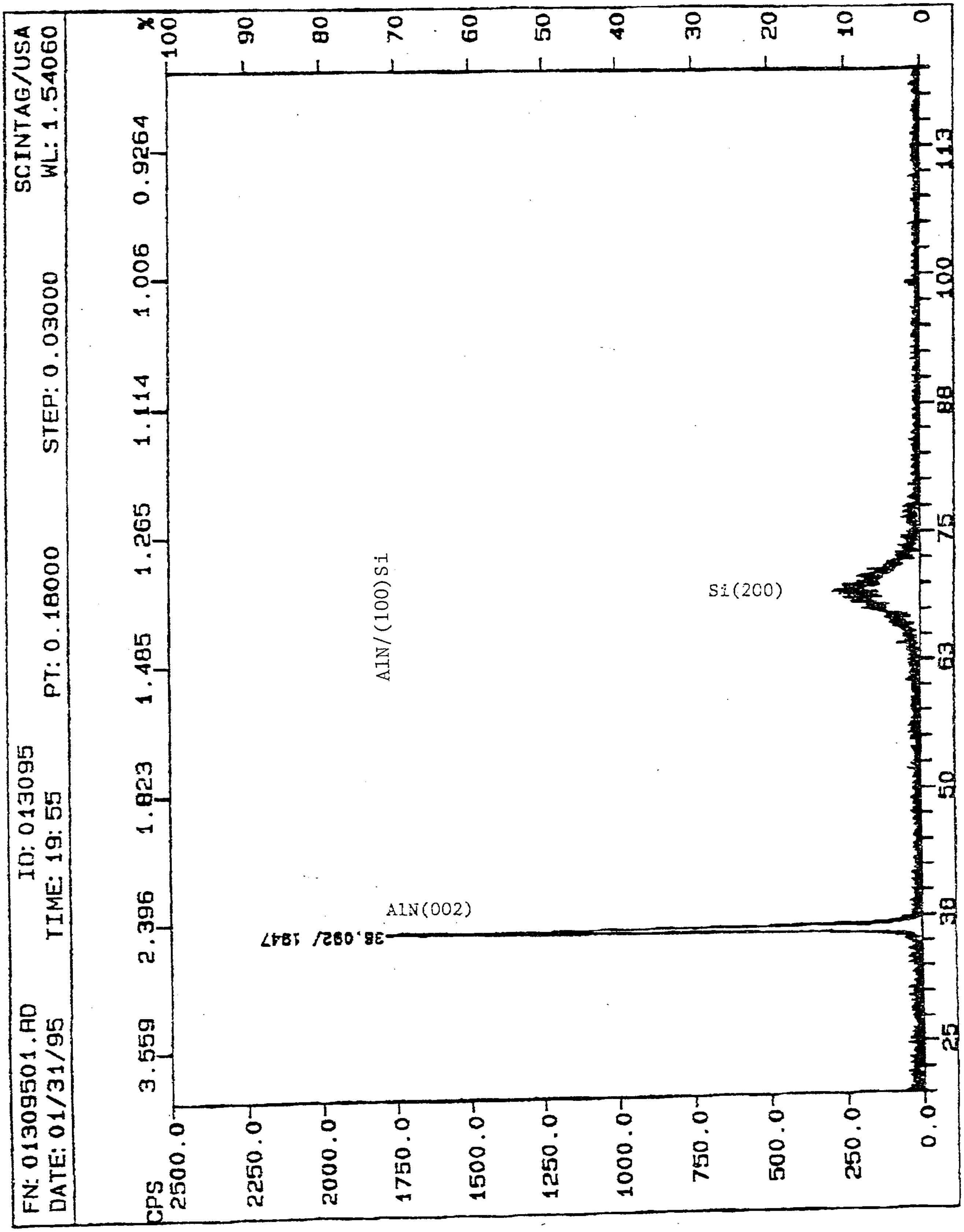


FIG. 1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SCINTAG/USA
WL: 1.54060
AlN/(100)Si
AlN(002)
38.082/ 1947
Si(200)
CPS
%

FIG. 2